



# **2012 Annual Summary of Water Quality Observations in Select Streams of Chesterfield County**



*Tributary to Proctors Creek west of Salem Church Road in Chesterfield, Virginia, October 2012*

**Chesterfield County  
Department of Environmental Engineering  
Water Quality Section**

**March 2013**

<b>Table of Contents:</b>	<b>Page</b>
Executive Summary .....	2
Introduction .....	3
Methods.....	4
Quality Assurance and Quality Control.....	5
Comparative Index of Chemical Water Quality .....	5
Site Descriptions and Summaries .....	6
Discussion.....	17
Conclusions.....	23
References.....	24

**List of Tables and Figures:**

<i>Table 1: Parameters and analytical methods .....</i>	<i>6</i>
<i>Table 2: Annual chemical water quality categorical observations for 10 streams of Chesterfield County .....</i>	<i>17</i>
<i>Table 3: Annual median values for water quality parameters .....</i>	<i>18</i>
<i>Table 4: Monitoring sites currently listed as impaired state waters .....</i>	<i>23</i>
<i>Figure 1: Water quality monitoring sites for 2012.....</i>	<i>3</i>
<i>Figure 2: Annual median pH observations among 10 sites within Chesterfield County.....</i>	<i>18</i>
<i>Figure 3: Annual median nitrate+nitrite nitrogen observations among 10 sites within Chesterfield County. ....</i>	<i>20</i>
<i>Figure 4: Annual median phosphate phosphorus observations among 10 sites within Chesterfield County .....</i>	<i>21</i>
<i>Figure 5: Annual median turbidity observations among 10 sites within Chesterfield County.....</i>	<i>22</i>

## Executive Summary

Ten stream sites were investigated during the year to monitor the general state of water quality throughout the county. These sites were monitored on a monthly basis.

A suite of instream parameters including dissolved oxygen, pH, conductivity, total dissolved solids, temperature and flow were measured at each site. Each month, samples were obtained and analyzed in the Water Quality Laboratory for ammonia and nitrate+nitrite nitrogen, phosphate phosphorus and turbidity. *E. coli* colony formation was measured on a bi-monthly basis. Fluoride and potassium concentrations were tested on a quarterly basis. Water quality observations were compiled and subjected to a set of calculations. These calculations categorized the streams' overall chemical health in one of three assessment categories: low, moderate and high water quality.

The majority (8) of the streams investigated during 2012 possessed moderate or high chemical water quality with low water quality observed at the remaining two sites. As in previous years, impacts to the streams were attributed to frequent low pH, elevated nutrient concentrations and increased turbidity measurements. All annual medians of physical parameters were within acceptable ranges during 2012 with the exception of pH at Winterpock Creek WQ-71 and Tributary to Timsbury Creek WQ-79, where pH values were below the state standard. *E. coli* counts indicated that concentrations do fluctuate with season and all median values met the state standard. Observations of fluoride and potassium indicated levels similar to those expected in groundwater.

Ammonia nitrogen concentrations were at acceptable levels during 2012 with only three streams having annual median values greater than 0.04 mg/L as N. Annual median nitrate+nitrite nitrogen concentrations were generally elevated with eight of the ten monitored sites having annual median concentrations greater than 0.10 mg/L as N. Annual median concentrations of phosphate phosphorus varied, with all streams demonstrating some degree of elevated phosphate phosphorus but all annual medians were less than or equal to 0.06mg/L as P. Turbidity measurements indicated generally clear waters throughout the county.

Annual rainfall for the county was approximately 26 inches, 18 inches below normal (average rainfall = 44 inches/year) for this area. Only three sample sites exhibited measureable flow throughout the year: Powwhite Creek WQ-70, Powwhite Creek WQ-75 and Timsbury Creek WQ-78. The seven remaining streams sites, experienced at least one instance of low flow (<0.01 m/s) conditions.

Three of the ten monitored sites are currently recorded on Virginia's impaired waters list. Each of the three streams is impaired for not supporting aquatic life. Powwhite Creek WQ-70 is also impaired for recreational contact. The three streams each suffer from different impairment causes. Powwhite Creek WQ-70 is impaired for *E. coli* bacteria and benthic macroinvertebrates. Timsbury Creek WQ-78 is impaired for pH. Lastly, Winterpock Creek WQ-71 is naturally impaired for dissolved oxygen.

## Introduction

This report presents the physical and chemical water quality data collected by Chesterfield County's Water Quality Section for the period of January through December of 2012. This report is a major monitoring component of the Watershed Assessment and Stream Protection Program (WASP) portion of Chesterfield County's VPDES Permit VA0088609. For this program element, ten stream sites were investigated during the year to monitor the general state of water quality throughout the county and to augment the database used for trending and comparison of physical and chemical parameters. These sites were monitored on a monthly basis. One of sites has multi-year data. During 2012, nine sites assessed in 2011 were rotated off the schedule and replaced with new sites on different stream reaches for a total of ten streams evaluated monthly. Powhite Creek WQ-70 was the only site from 2011 that remained a part of the sampling regime.

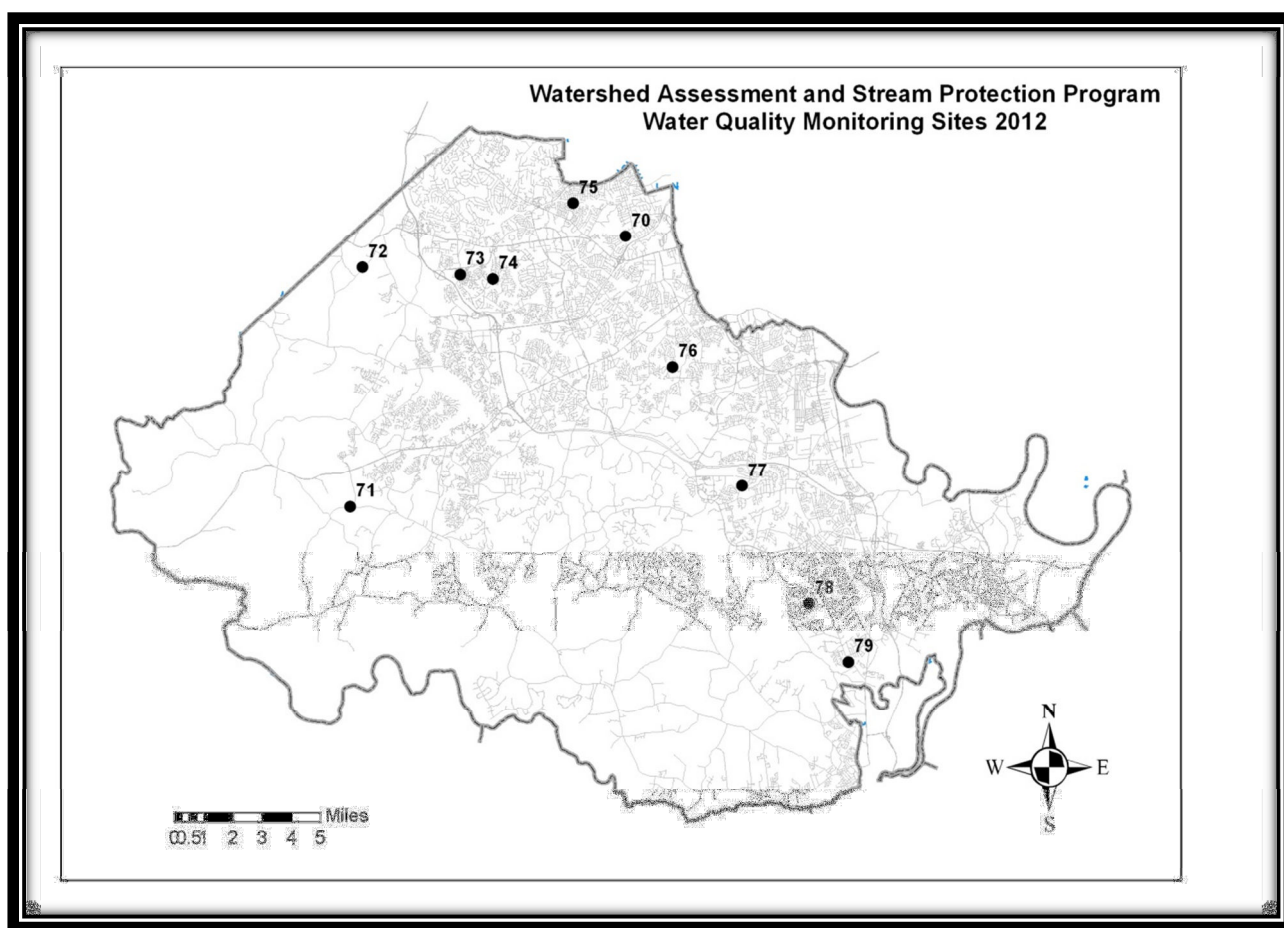


Figure 1. Water Quality Monitoring Sites for 2012

Stream sites were selected after a review of previous sites and watersheds assessed using maps produced from the county's Geographic Information System. Streams were selected to represent a variety of sizes and watersheds. Following the map analysis, field surveys were conducted to verify each site location's accessibility and feasibility. A list of stream sites was finalized and assigned a specific reference identifier consisting of the prefix "WQ" (*i.e.* water quality)

followed by a sequentially increasing number (01 – 79) to differentiate them from other WASP monitoring sites. Monitoring in 2012 followed the methods and protocols used in previous years.

## Methods

Stream sites were sampled monthly over a range of baseflow conditions. Physical parameters were measured *in situ* with a Hydrolab<sup>®</sup> Minisonde water quality multiprobe in conjunction with a Surveyor 4a data logger system. The Hydrolab<sup>®</sup> Minisonde multiprobe was calibrated using commercially prepared buffer solutions prior to deployment to the field. These calibrations were rechecked upon return from the field to ensure the probe maintained calibration during use. Parameters measured in the field included water temperature, pH, dissolved oxygen, conductivity, total dissolved solids and depth. A semi-quantitative measure of flow was also obtained onsite by recording the time it took for a float to travel one meter. Ambient air temperature was additionally noted.

Water quality samples were collected in 237 ml low-density polyethylene containers. Samples were obtained from the bank of each site just below the surface of the water by hand or a long handled sampling pole and placed in a cooler on ice for transfer to the water quality laboratory. Upon returning to the laboratory, sample information was recorded and each sample assigned a unique lab identification number in an EXCEL spreadsheet. Samples were then stored at  $\leq 4^{\circ}\text{C}$  in the laboratory refrigerator until time of analysis. Care was taken to adhere to analytical holding times for specific analytes.

In the laboratory, water samples were analyzed monthly for four parameters: ammonia nitrogen, nitrate+nitrite nitrogen, phosphate phosphorus and turbidity. Fluoride and potassium concentrations were analyzed on a quarterly basis. The fluoride and potassium analytes were added in 2010 to establish their naturally occurring background levels within county waters to aid in future stormwater pollution prevention efforts. Both fluoride and potassium occur naturally in ground and surface waters but they can also be indicators of pollution. Elevated fluoride is a potential indicator of drinking/tap water intrusion and elevated potassium levels are an indicator of industrial and commercial wastes. Both can be a potential indicator of sanitary wastewater but bacterial counts are the best indicator of sewage. On a bi-monthly schedule, the samples were tested for *Escherichia coli* (*E. coli*). In 2011, *E. coli* was added to the testing parameters because fecal bacteria contamination of surface waters in Virginia has been identified by the Virginia Department of Environmental Quality (VADEQ) as a problem in Virginia. Many streams in the state, including in Chesterfield County, have been listed by the VADEQ as impaired as a result of bacterial contamination. With the addition of *E. coli* testing, a baseline for colony concentrations in the streams may be developed and streams with potential fecal contamination may be identified. Nutrient and chemical analyses were conducted using a Palintest<sup>®</sup> 8000 series photometer. Palintest<sup>®</sup> environmental testing company methods specific to the photometer were used and generally reflected those outlined in *Standard Methods*. Turbidity was measured using a Cole-Parmer nephelometric turbidimeter following procedures outlined in *Standard Methods*. *E. coli* was measured using the Coliscan<sup>®</sup> Easygel<sup>®</sup> method.

## Quality Assurance and Quality Control

For each parameter analyzed in the laboratory, Method Detection Limits (MDLs) were calculated (study conducted November 2011) following the procedure outlined in Section 1030E of *Standard Methods*. Laboratory reporting limits were determined from these MDLs. On the day of sample analysis, instrument calibration was verified using a set of photometer primary standards obtained from Palintest®. To insure analytical precision and accuracy, known quality control samples for ammonia nitrogen, nitrate+nitrite nitrogen and phosphate phosphorus were analyzed. Values obtained were compared to the manufacturer's acceptable recovery limits. Out of tolerance values were noted and evaluated for potential causes of error. Due to lack of availability, known concentrations of fluoride, potassium and *E. coli* were not analyzed. Instrument calibration for the turbidimeter was checked and verified prior to analysis using secondary standards applicable to the range of turbidity expected.

Sample replicates were analyzed every ten samples for each parameter and relative percent differences were calculated. Analytical blanks were used in order to detect any potential contamination that may have occurred during sampling or sample preparation. Manufacturer's recommendations for preventive maintenance were followed for all instruments.

A summary of the tests, methods and reporting limits as well as applicable water quality standards for the analyses are outlined in Table 1.

## Comparative Index of Chemical Water Quality

The index of water quality developed and used for the 2002 - 2011 data to describe relative chemical water quality among the sites continued in 2012. Monthly water quality measurements were entered into an EXCEL spreadsheet and quality scores were assigned based upon values obtained from literature and a web based search of Virginia, Mid-Atlantic States and Regional EPA water quality standards. The measurement scores were summed and compared to an ideal score (*i.e.* the score if all measurements met the standards). Cumulative percentile plot analysis resulted in a set of three criteria based upon natural breaks in the data (generally the 25<sup>th</sup> and 75<sup>th</sup> percentile). These data sets were categorically identified respectively as "high," "moderate" and "low" quality. Annual median scores were calculated and used to characterize the overall chemical water quality for each site. It should be noted that the index should not be interpreted as a full measure of aquatic health as it only relates to the identified parameters relative to the 2012 data set. Other indices that incorporate benthic macroinvertebrate and instream habitat data may yield a different assessment and should not be compared to the results of this analysis. A copy of the EXCEL spreadsheet with the calculations will be made available for review upon request.



Table 1. Parameters and Analytical Methods

Parameter	Analytical Method	Reporting Limit	Water Quality Standard	Reference
Dissolved Oxygen	Probe: Hydrolab <sup>®</sup> Minisonde	0.1 mg/L*	≥ 4.0 mg/L	VADEQ
pH	Probe: Hydrolab <sup>®</sup> Minisonde	0.2 units*	6.0 – 9.0 units	VADEQ
Conductivity	Probe: Hydrolab <sup>®</sup> Minisonde	1.0 µS/cm*	≤ 500 µS/cm	None
Total Dissolved Solids	Probe: Hydrolab <sup>®</sup> Minisonde	0.1 mg/L*	≤ 500 mg/L	PA State Standard
Temperature	Probe: Hydrolab <sup>®</sup> Minisonde	0.1 °C*	≤ 32 °C	VADEQ
Fluoride	Palintest <sup>®</sup> : Photometric	0.15 mg/L	0.13 mg/L Groundwater	Brown & Caraco, 2004
Potassium	Palintest <sup>®</sup> : Na <sup>+</sup> Tetraphenyl	0.3 mg/L	3.1 mg/L Groundwater	Brown & Caraco, 2004
Ammonia Nitrogen	Palintest <sup>®</sup> : Phenate	0.02 mg/L	0.04 mg/L Forested Area	Schueler, 1997b
Nitrate/Nitrite Nitrogen	Palintest <sup>®</sup> : Nitratest	0.02 mg/L	0.10 mg/L Nitrate+Nitrite	USEPA, 2000
Phosphate Phosphorus	Palintest <sup>®</sup> : Phosphate LR	0.02 mg/L	0.01 mg/L Forested Area	Caraco, 2001
Turbidity	Standard Method 2130B Nephelometric	1.0 NTUs	4 NTUs	USEPA, 2000
<i>Escherichia coli</i>	Coliscan <sup>®</sup> Easygel <sup>®</sup>	20CFU/100mL*	235CFU/100mL	VADEQ
Flow	USGS: Float	0.01 m/s	None	None

\*When a method detection limit was not applicable for a parameter, it was replaced by an estimation of accuracy based on manufacturer's specifications.

### Site Descriptions and Summaries

The following pages describe each site and contain a summary of the observations made during the course of the year. All photos depict upstream views unless otherwise noted. Left and right banks are referenced from the perspective looking upstream. Latitude and longitude are reported in decimal degrees. Field data sheets and associated notes are located in Appendix A following this report.

**Site Number WQ-70**

Stream: Powwhite Creek

Site: Approximately 100 meters downstream  
of W. Pinetta Drive, Bon Air, Virginia

Latitude: 37.50694

Longitude: 77.55749

Watershed: James River

Stream Order: 2

Land use: Residential and forest

Gradient: Low

Field and Laboratory Observations:



Date	Dissolved Oxygen (mg/L)	pH (units)	Conductivity (microS/cm)	Total Dissolved Solids (mg/L)	Temperature (Degrees C)	Ammonia (mg/L as N)	Nitrate+Nitrite (mg/L as N)	Phosphate (mg/L as P)	Turbidity (NTUs)	E. Coli CFU/100mL	Flow m/s	Index Score %Comparison
01/24/12	11.6	6.6	106	67.8	8.2	0.05	0.27	0.03	4.2	*	0.43	73.3
02/21/12	12.0	6.4	200	128.1	6.2	0.05	0.22	0.08	6.0	40	0.45	68.8
03/19/12	8.7	6.7	123	78.9	16.8	0.02	0.09	0.04	5.6	*	0.44	86.7
04/17/12	6.4	6.6	125	79.9	20.2	0.09	0.12	0.05	6.1	<20	0.33	75.0
05/16/12	6.9	6.7	115	73.4	20.7	0.07	0.12	0.06	6.0	*	0.38	73.3
06/12/12	6.0	6.6	118	75.4	23.1	0.08	0.13	0.06	5.9	60	0.31	75.0
07/16/12	5.3	6.4	88	56.0	26.7	0.11	0.14	0.15	7.0	*	0.14	73.3
08/16/12	5.2	6.4	96	61.3	25.7	0.09	0.12	0.06	5.8	<20	0.19	75.0
09/17/12	6.7	6.5	111	70.6	19.1	0.07	0.07	0.08	6.4	*	0.05	80.0
10/22/12	7.2	6.5	94	60.3	13.8	0.02	0.36	0.05	4.3	60	0.41	81.3
11/19/12	9.0	6.5	119	76.3	9.8	0.04	0.03	0.11	5.6	*	0.22	86.7
12/17/12	9.6	6.3	122	77.9	10.0	0.03	0.07	0.11	7.1	40	0.23	87.5
Minimum	5.2	6.3	88	56.0	6.2	0.02	0.03	0.03	4.2	<20	0.05	68.8
Median	7.0	6.5	116	74.4	17.9	0.06	0.12	0.06	6.0	40	0.32	75.0
Maximum	12.0	6.7	200	128.1	26.7	0.11	0.36	0.15	7.1	60	0.45	87.5
2011 Median	6.9	6.5	121	78.0	15.0	0.06	0.17	0.05	5.7	90.0	0.31	75.0

This is the second consecutive year this site has been evaluated and is approximately two and a half miles downstream of the sampling site Tributary to Powwhite Creek WQ-75. Powwhite Creek is a perennial tributary of the James River located in the Piedmont region of Chesterfield County. The stream's substrate is composed of firm sand and gravel; samples were taken from a large sand bar where emergent aquatic plant vegetation grew during the warm seasons. The stream was observed to have strong flows throughout the year. The water appeared clear and stained an equal number of times during the year. This is an increase of stained observations over last year when the creek appeared stained only twice. The banks appeared slight to moderately eroded with an erosion scar visible on the left bank above the baseflow waterline along most of the stream reach. The banks were well vegetated along the stream reach. The riparian buffer consisted of trees, shrubs with warm season herbaceous growth. Periphyton was observed throughout the year. Algae, *Corbicula* shells, fish and damselflies were observed at various times. This site continues to be visited by wildlife as deer and raccoon tracks were frequently observed in the sand bar.

Samples were obtained from the left bank at a median depth of 0.18 meters. The annual median index score (75.0%) was unchanged from the previous year and indicated moderate water quality. All annual medians of the chemical parameters were within acceptable ranges. There were no incidences of dissolved oxygen or pH violating state water quality standards. The annual median turbidity was 6.0 NTUs supporting observation of clear to stained water during the year. The annual median ammonia nitrogen concentration was 0.06 mg/L as N; the second highest median observed among sites and consistent with last year's median. The nitrate-nitrogen annual median was 0.12 mg/L as N. The phosphate phosphorus annual median was 0.06 mg/L as P; the highest observed among all sites. The *E. coli* median was 40 CFU/100mL. The median fluoride value was below the reporting limit of 0.15 mg/L indicating levels similar to groundwater. The potassium annual median was 3.2 mg/L, similar to expected groundwater concentrations.



**Site Number WQ-71**

Stream: Winterpock Creek

Site: Approximately 20 meters upstream  
of Beach Road, Matoaca, Virginia

Latitude: 37.37402

Longitude: 77.73029

Watershed: Appomattox River

Stream Order: 2

Land use: Forested with some residential

Gradient: Low

Field and Laboratory Observations:



Date	Dissolved Oxygen (mg/L)	pH (units)	Conductivity (microS/cm)	Total Dissolved Solids (mg/L)	Temperature (Degrees C)	Ammonia (mg/L as N)	Nitrate+Nitrite (mg/L as N)	Phosphate (mg/L as P)	Turbidity (NTUs)	E. Coli (CFU/100mL)	Flow m/s	Index Score %Comparison
01/24/12	11.5	5.6	48	30.6	7.5	<0.02	0.02	<0.02	3.0	*	0.20	93.3
02/21/12	12.8	5.5	75	47.8	3.6	<0.02	0.08	0.03	4.5	<20	0.25	87.5
03/19/12	9.6	5.9	44	28.2	12.9	<0.02	<0.02	0.04	3.9	*	0.17	86.7
04/17/12	8.0	5.9	45	28.5	16.6	<0.02	0.04	<0.02	3.4	20	0.08	93.8
05/16/12	8.3	6.0	42	27.2	16.8	<0.02	0.02	0.05	4.7	*	0.10	93.3
06/12/12	2.4	5.6	68	43.3	18.6	0.07	0.03	<0.02	4.1	80	<0.01	81.3
07/16/12	*	*	*	*	*	*	*	*	*	*	*	*
08/16/12	*	*	*	*	*	*	*	*	*	*	*	*
09/17/12	*	*	*	*	*	*	*	*	*	*	*	*
10/22/12	3.8	5.3	52	33.2	11.3	<0.02	0.04	<0.02	3.8	120	<0.01	87.5
11/19/12	8.6	5.2	44.4	28.2	8.9	<0.02	0.02	0.04	2.0	*	<0.01	86.7
12/17/12	8.5	5.1	39	24.8	10.3	<0.02	0.02	0.07	2.2	<20	0.02	87.5
Minimum	2.4	5.1	39	24.8	3.6	<0.02	<0.02	<0.02	2.0	<20	<0.01	81.3
Median	8.5	5.6	45	28.5	11.3	<0.02	0.02	0.03	3.8	20	0.08	87.5
Maximum	12.8	6.0	75	47.8	18.6	0.07	0.08	0.07	4.7	120	0.25	93.8

This monthly sampling site on Winterpock Creek was established in January of 2012. Winterpock Creek is a perennial tributary of the Appomattox River located in the Triassic region of Chesterfield County. The substrate is composed of firm sand and gravel with some interspersed cobble. Flow at this site was typically low with only six observations of measureable water movement. From July through September, there was no water observed in the creek. During the nine months when water was present, it appeared clear with one instance of stained appearance. The stream banks were moderately to heavily eroded. The riparian buffer was well forested with trees and shrubs and some herbaceous plants. When water was present, periphyton was observed. Also observed were water striders, iron bacteria and algae.

Samples were obtained from the right bank at a median depth of 0.07 meters. The annual median index score (87.5%) indicated high chemical water quality; one of two sites with this ranking this year. All annual medians of chemical parameters were within acceptable ranges except for pH. The annual pH median (5.6 units) violated the state water quality standard and was the lowest annual pH among sites. Dissolved oxygen (annual median 8.5) violated the state water quality standard twice during the year. The dissolved oxygen finding is not unusual as this stream is listed as a naturally impaired waterway by VADEQ for dissolved oxygen. The annual median conductivity (45  $\mu$ S/cm) and total dissolved solids (28.5 mg/L) were the lowest among all sites. These observations correspond with the lowest annual turbidity median 3.8 NTUs among all sites. The annual median ammonia nitrogen level was below the method detection limit, <0.02 mg/L as N. The nitrate+nitrite annual median was 0.02 mg/L as N, the lowest nitrate+nitrite median observed among sites. The phosphate phosphorus annual median was 0.03 as P. The *E. coli* annual median concentration was 20 CFU/100mL and was among the two lowest median *E. coli* concentrations. The median fluoride concentration was the highest seen among the sites at 0.32 mg/L but still indicated levels similar to groundwater. The potassium annual median was 2.3 mg/L, similar to expected groundwater concentrations.

**Site Number WQ-72**

Stream: Tributary to Swift Creek

Site: Approximately 30 meters right of Mt. Hermon Road, Midlothian, Virginia

Latitude: 37.49285

Longitude: 77.72143

Watershed: Appomattox River

Stream Order: 1

Land use: Forested with some residential

Gradient: Low



Field and Laboratory Observations:

*View is downstream*

Date	Dissolved Oxygen (mg/L)	pH (units)	Conductivity (microS/cm)	Total Dissolved Solids (mg/L)	Temperature (Degrees C)	Ammonia (mg/L as N)	Nitrate+Nitrite (mg/L as N)	Phosphate (mg/L as P)	Turbidity (NTUs)	E. Coli CFU/100mL	Flow m/s	Index Score %Comparison
01/24/12	12.2	6.1	56	35.6	6.9	0.02	0.14	0.02	7.5	*	0.09	80.0
02/21/12	13.0	6.1	51	32.2	3.9	0.03	0.12	0.02	11.7	240	0.28	68.8
03/19/12	10.3	6.6	74	47.2	13.9	<0.02	0.04	0.04	11.3	*	0.05	80.0
04/17/12	7.4	6.6	114	72.5	17.7	<0.02	0.04	0.02	6.1	60	<0.01	87.5
05/16/12	8.3	6.6	89	57.1	17.2	0.07	0.13	0.04	19.2	*	0.02	60.0
06/12/12	0.8	6.4	158	101.7	19.1	0.17	0.08	0.03	8.9	20	<0.01	62.5
07/16/12	4.3	6.5	104	66.5	23.7	0.04	0.18	0.05	23.9	*	<0.01	66.7
08/16/12	*	*	*	*	*	*	*	*	*	*	*	*
09/17/12	*	*	*	*	*	*	*	*	*	*	*	*
10/22/12	*	*	*	*	*	*	*	*	*	*	*	*
11/19/12	4.9	4.1	152	97.2	9.8	<0.02	0.03	0.03	5.3	*	<0.01	80.0
12/17/12	6.2	6.2	134	85.9	10.9	<0.02	0.03	0.02	4.4	20	<0.01	93.8
Minimum	0.8	4.1	51	32.2	3.9	<0.02	0.03	0.02	4.4	20	<0.01	60.0
Median	7.4	6.4	104	66.5	13.9	0.02	0.08	0.03	8.9	40	<0.01	80.0
Maximum	13.0	6.6	158	101.7	23.7	0.17	0.18	0.05	23.9	240	0.28	93.8

This monthly sampling site on Tributary to Swift Creek was established in January of 2012. Tributary to Swift Creek is a perennial tributary flowing towards the Appomattox River located in the Triassic region of Chesterfield County. The stream's substrate is primarily comprised of sand, gravel and cobble. Flow at this site was poor with only three observations of measureable water movement. Supporting these low flow observations, there was often observed a preponderance of allochthonous input along the stream banks and grade changes along this stream segment. From July through September, there was no water observed in the creek. The water appeared stained on five visits and clear on four. The banks were heavily eroded indicating this stream may subject to fast, flashy flows during storm events. The riparian area consisted of well forested land dominated by trees and shrubs. Periphyton was observed on each visit except one. Other biota observed were algae, water striders and frogs.

Samples were obtained from the right bank at a median depth of 0.07 meters. The annual median index score (80.0%) indicated moderate chemical water quality. All annual medians of the chemical parameters were within acceptable ranges. However, during November, both dissolved oxygen (4.9 mg/L) and pH (4.1 units) violated state water quality standards. The annual median turbidity (8.9 NTUs), the second highest median observed, supported the observation of frequently stained water. The annual median ammonia nitrogen concentration was 0.02 mg/L as N. The annual nitrate+nitrite concentration was 0.08 mg/L as N. The phosphate phosphorus annual median was 0.03 mg/L as P. The annual median *E. coli* concentration was 40 CFUs/100mL. In February, there was one instance of violating the state bacterial water quality standard with 240 CFUs/100mL. The annual median fluoride concentration was 0.22 mg/L, indicating levels similar to groundwater. The annual potassium median concentration (3.2 mg/L) indicated levels similar to ground water.



**Site Number WQ-73**

Stream: Little Tomahawk Creek

Site: Approximately 50 meters upstream  
of the Woodland Creek Way crossing,  
Midlothian, Virginia

Latitude: 37.48887

Longitude: 77.66063

Watershed: Appomattox River

Stream Order: 1

Land use: Residential townhomes and  
commercial

Gradient: Low



## Field and Laboratory Observations:

Date	Dissolved Oxygen (mg/L)	pH (units)	Conductivity (microS/cm)	Total Dissolved Solids (mg/L)	Temperature (Degrees C)	Ammonia (mg/L as N)	Nitrate+Nitrite (mg/L as N)	Phosphate (mg/L as P)	Turbidity (NTUs)	E. Coli (CFU/100mL)	Flow m/s	Index Score %Comparison
01/24/12	11.5	6.2	105	67.4	9.0	0.02	0.25	<0.02	3.7	*	0.49	86.7
02/21/12	12.2	6.1	333	213.4	6.8	0.02	0.25	0.02	4.0	20	0.42	81.3
03/19/12	10.8	6.3	115	74.0	14.4	<0.2	0.17	<0.02	3.4	*	0.43	93.3
04/17/12	9.4	6.2	97	62.3	17.4	<0.02	0.11	<0.02	2.6	420	0.32	87.5
05/16/12	8.9	6.2	85	54.4	18.4	<0.02	0.15	0.02	6.9	*	0.32	80.0
06/12/12	8.5	6.1	121	77.4	20.5	<0.02	0.12	<0.02	3.8	280	0.18	87.5
07/16/12	7.8	6.3	133	85.1	24.9	<0.02	0.22	0.02	6.9	*	0.21	73.3
08/16/12	8.2	6.2	156	99.6	24.1	<0.02	0.10	<0.02	3.0	20	0.05	100.0
09/17/12	8.4	6.1	148	95.0	20.3	<0.02	0.07	0.07	3.4	*	0.20	93.3
10/22/12	8.9	6.3	135	86.1	15.5	<0.02	0.09	0.03	4.7	500	0.20	87.5
11/19/12	9.9	6.7	126	81.2	11.5	0.02	0.05	0.03	10.0	*	<0.01	80.0
12/17/12	9.8	6.1	124	79.3	12.0	<0.02	0.13	0.05	4.5	<20	0.13	87.5
Minimum	7.8	6.1	85	54.4	6.8	<0.02	0.05	<0.02	2.6	<20	<0.01	73.3
Median	9.1	6.2	125	80.3	16.4	<0.02	0.13	0.02	3.9	150	0.21	87.5
Maximum	12.2	6.7	333	213.4	24.9	0.02	0.25	0.07	10.0	500	0.49	100.0

This monthly sampling site on Little Tomahawk Creek was established in January of 2012. Little Tomahawk Creek is a perennial tributary in the Appomattox River watershed located in the High River Terrace region of Chesterfield County. The stream's substrate is comprised of sand, gravel and some cobble. The stream exhibited flow throughout most of the year; in November, low flow was observed. The water flowed clear throughout most of the year with once incidence of turbid appearance, which also occurred in November. The stream is heavily eroded with its parent material exposed along the banks and streambed. The riparian area is narrowly treed and shrubbed with a parking lot and apartment complex being its dominant feature. Periphyton and algae were seen at various times throughout the year and minnows were observed on five occasions.

Samples were obtained from the left bank at a median depth of 0.04 meters. The annual median index score (87.5%) indicated high chemical water quality, one of two sites this year with this distinction. All annual median chemical parameters were within acceptable ranges. All dissolved oxygen and pH measurements were acceptable by the state water quality standards. The dissolved oxygen annual median (9.1 mg/L) was the highest median observed among the sites. The turbidity annual median was 3.9 NTUs, supporting the observation of clear water throughout most of the year. The annual median ammonia nitrogen (<0.02 mg/L as N) was one of the two lowest ammonia medians seen during the year. The nitrate+nitrite annual median was 0.13 mg/L as N. The phosphate phosphorus annual median concentration was one of the three lowest concentrations seen among the sites at 0.02mg/L as P. The median *E. coli* concentration was 150 CFUs/100mL with three, half of the measurements, violations of the state water quality bacterial standard. The median fluoride value was below the reporting limit of 0.15 mg/L indicating levels similar to those found in ground water. The potassium annual median (2.3 mg/L) was similar to expected groundwater levels and was one of the two lowest observed medians of all sites.

**Site Number WQ-74**

Stream: Tributary to Falling Creek

Site: Approximately 10 meters  
downstream of Queensgate Road crossing,  
Midlothian, Virginia

Latitude: 37.48659

Longitude: 77.64034

Watershed: James River

Stream Order: 1

Land use: Residential and forested park

Gradient: Low

*View is downstream*

Field and Laboratory Observations:

Date	Dissolved Oxygen (mg/L)	pH (units)	Conductivity (microS/cm)	Total Dissolved Solids (mg/L)	Temperature (Degrees C)	Ammonia (mg/L as N)	Nitrate+Nitrite (mg/L as N)	Phosphate (mg/L as P)	Turbidity (NTUs)	E. Coli CFU/100mL	Flow m/s	Index Score %Comparison
01/24/12	12.2	6.5	104	66.9	7.3	0.02	0.31	<0.02	8.3	*	0.24	73.3
02/21/12	12.2	6.3	181	115.4	7.2	<0.02	0.23	0.05	5.0	200	0.19	75.0
03/19/12	9.3	6.6	159	101.4	17.8	0.06	0.31	<0.02	6.0	*	0.30	73.3
04/17/12	7.9	6.4	127	81.3	19.6	0.03	0.12	<0.02	4.6	260	0.05	87.5
05/16/12	7.6	6.5	110	69.9	20.7	0.05	0.12	0.02	7.9	*	0.14	73.3
06/12/12	7.1	6.3	115	73.7	21.0	0.04	0.18	0.02	5.9	80	0.06	81.3
07/16/12	6.6	6.4	97	62.0	27.1	0.03	0.08	<0.02	8.7	*	0.14	86.7
08/16/12	6.8	6.4	140	89.0	24.3	0.07	0.35	0.03	6.9	100	0.05	68.8
09/17/12	7.9	5.9	104	66.2	19.2	0.14	0.52	0.02	9.0	*	0.12	46.7
10/22/12	7.4	6.6	177	112.8	12.4	<0.02	0.06	0.07	2.8	200	<0.01	93.8
11/19/12	4.5	6.6	184	118.1	10.7	0.02	0.02	0.18	9.8	*	<0.01	73.3
12/17/12	6.1	6.3	205	131.1	11.2	<0.02	0.03	0.16	5.1	20	0.03	87.5
Minimum	4.5	5.9	97	62.0	7.2	<0.02	0.02	<0.02	2.8	20.0	<0.01	46.7
Median	7.5	6.4	133	85.2	18.5	0.03	0.15	0.02	6.5	150	0.09	74.2
Maximum	12.2	6.6	205	131.1	27.1	0.14	0.52	0.18	9.8	260	0.30	93.8

This monthly sampling site on Tributary to Falling Creek was established in January of 2012. Tributary to Falling Creek is a perennial tributary in the James River watershed located in the Piedmont and Alluvium region of Chesterfield County. The creek's substrate is comprised of sand, gravel and some cobble/rip rap at the top of the sampling reach. Flow was observed during most of the year with water consistently present, but flow was immeasurable during October and November. The stream appeared clear and stained on an equal number of observations. The banks were well vegetated and were slightly to moderately eroded. The riparian area vegetation consisted of trees and shrubs with herbaceous growth seen during warm seasons. The riparian corridor was narrow and both sides flanked by residential yards. Periphyton was observed during each visit and algae, emergent plants, and fish seen on multiple occasions.

Samples were obtained from the right bank at a median depth of 0.18 meters. The annual median index score (74.2%) indicated moderate chemical water quality. All annual medians of the chemical parameters were within acceptable ranges. There were no violations of the state dissolved oxygen or pH water quality standard. The annual median conductivity (133  $\mu$ S/cm) and total dissolved solids (85.2 mg/L) were the highest among all sites. The turbidity annual median was 6.5 NTUs. The nutrient concentrations at this site were low overall. The annual median ammonia nitrogen concentration was 0.03 mg/L as N. The annual median nitrate+nitrite concentration was 0.15 mg/L as N. The phosphate phosphorus annual median concentration was one of the three lowest concentrations seen among the sites at 0.02mg/L as P. The median *E. coli* concentration was 150 CFUs/100mL with one violation of the state water quality bacterial standard during the year. The median fluoride concentration was 0.25 mg/L indicating levels similar to expected groundwater levels. The potassium annual median (3.5 mg/L) was the highest seen among the sites but still similar to expected groundwater levels.



**Site Number WQ-75**

Stream: Powwhite Creek

Site: Approximately 30 meters upstream  
of White Rabbit Road crossing, Bon Air,  
Virginia

Latitude: 37.52377

Longitude: 77.58997

Watershed: James River

Stream Order: 1

Land use: Residential and forested areas

Gradient: Low



## Field and Laboratory Observations:

Date	Dissolved Oxygen (mg/L)	pH (units)	Conductivity (microS/cm)	Total Dissolved Solids (mg/L)	Temperature (Degrees C)	Ammonia (mg/L as N)	Nitrate+Nitrite (mg/L as N)	Phosphate (mg/L as P)	Turbidity (NTUs)	E. Coli CFU/100mL	Flow m/s	Index Score %Comparison
01/24/12	11.8	6.4	100	64.1	9.2	0.02	0.22	<0.02	6.3	*	0.44	80.0
02/21/12	12.2	6.3	153	97.8	7.6	<0.02	0.19	<0.02	5.6	<20	0.41	87.5
03/19/12	10.9	6.6	107	68.5	14.9	<0.02	0.26	<0.02	4.1	*	0.27	86.7
04/17/12	7.7	6.3	109	69.6	17.4	0.08	0.18	0.04	3.0	<20	0.30	81.3
05/16/12	8.0	6.4	107	68.2	18.5	0.05	0.25	0.03	4.0	*	0.29	73.3
06/12/12	6.9	6.3	117	74.9	20.1	0.05	0.21	0.05	7.2	60	0.10	75.0
07/16/12	6.5	6.4	128	82.2	23.7	0.05	0.19	0.08	4.6	*	0.16	80.0
08/16/12	6.8	6.5	147	94.0	23.2	0.05	0.20	0.04	3.8	140	0.08	81.3
09/17/12	7.3	6.4	161	102.5	18.5	0.04	0.19	0.06	5.1	*	0.03	80.0
10/22/12	8.8	6.6	113	72.1	13.0	<0.02	0.07	0.02	2.9	140	0.19	93.8
11/19/12	8.3	6.1	127	81.0	10.1	<0.02	0.05	0.08	2.8	*	0.19	93.3
12/17/12	9.3	6.2	115	73.4	11.5	<0.02	0.05	0.07	3.0	40	0.23	87.5
Minimum	6.5	6.1	100	64.1	7.6	<0.02	0.05	<0.02	2.8	<20	0.03	73.3
Median	8.1	6.4	116	74.2	16.2	0.03	0.19	0.04	4.1	50	0.21	81.3
Maximum	12.2	6.6	161	102.5	23.7	0.08	0.26	0.08	7.2	140	0.44	93.8

This monthly sampling site on Powwhite Creek was established in January of 2012 and is approximately two and a half miles upstream of the sampling site Powwhite Creek WQ-70. Powwhite Creek is a perennial tributary of the James River and this upper segment is located in the High River Terrace region of Chesterfield County. The stream substrate is comprised of sand, gravel and cobble. The stream bed had large extensive sand/gravel bars that were exposed during most of the year and can be seen in the above photo. This creek exhibited strong, measurable flow throughout the year. The water was observed as clear or stained during the year. The banks were well vegetated appearing slightly eroded. The riparian area consisted of trees and shrubs with herbaceous growth present during the summer months. Periphyton was observed throughout the year. Observations of algae, emergent plants and fish were also made.

Samples were obtained from the left bank at a median depth of 0.07 meters. The annual median index score (81.3%) indicated moderate chemical water quality. As with the Powwhite Creek WQ-70 site downstream, all annual medians of the chemical parameters were within acceptable ranges. There were no instances of dissolved oxygen concentrations (annual median 8.1 mg/L) or pH (annual median 6.4 units) violating state standards. The annual median conductivity (116  $\mu$ S/cm) and total dissolved solids (74.2 mg/L) were virtually identical to the annual medians observed at the downstream Powwhite Creek (WQ-70) sampling location. The annual median turbidity was 4.1 NTUs, supporting the predominant observations of clear water. The annual median ammonia nitrogen concentration was 0.03 mg/L as N. The annual median nitrate+nitrite concentration was 0.19 mg/L as N. The phosphate phosphorus annual median was 0.04 mg/L as P. The annual median *E. coli* was 50 CFUs/100mL with no violations in the state bacterial water standard. The median fluoride concentration was 0.20 mg/L indicating levels similar to expected groundwater levels. The potassium annual median (2.8 mg/L) was also similar to expected groundwater levels.



**Site Number WQ-76**

Stream: Tributary to Falling Creek

Site: Approximately 10 meters  
downstream Barkbridge Road crossing,  
North Richmond, Virginia

Latitude: 37.44195

Longitude: 77.52907

Watershed: James River

Stream Order: 2

Land use: Residential and forested

Gradient: Low:

*View is downstream*

Field and Laboratory Observations:

Date	Dissolved Oxygen (mg/L)	pH (units)	Conductivity (microS/cm)	Total Dissolved Solids (mg/L)	Temperature (Degrees C)	Ammonia (mg/L as N)	Nitrate+Nitrite (mg/L as N)	Phosphate (mg/L as P)	Turbidity (NTUs)	E. Coli CFU/100mL	Flow m/s	Index Score %Comparison
01/24/12	11.5	6.3	77	48.8	7.2	0.05	0.12	0.05	9.9	*	0.32	66.7
02/21/12	11.9	6.4	76	48.4	6.7	<0.02	0.10	0.02	12.0	140	0.26	75.0
03/19/12	8.4	6.4	88	56.3	17.2	0.04	0.09	0.02	7.1	*	0.14	86.7
04/17/12	6.2	6.3	89	57.0	19.5	0.07	0.18	0.05	4.9	<20	0.06	81.3
05/16/12	6.6	6.3	74	47.4	20.6	0.05	0.11	0.04	6.5	*	0.13	73.3
06/12/12	4.7	6.3	92	58.8	20.6	0.08	0.26	0.04	6.9	80	0.05	68.8
07/16/12	5.0	4.9	91	57.8	24.7	0.07	0.24	0.08	5.5	*	0.04	60.0
08/16/12	5.4	6.5	95	60.7	24.0	0.05	0.23	0.07	5.4	160	0.03	68.8
09/17/12	6.3	6.3	81	52.3	18.5	0.05	0.19	0.06	3.9	*	0.05	80.0
10/22/12	6.0	6.4	86	55.2	12.6	<0.02	0.09	0.05	2.9	<20	<0.01	93.8
11/19/12	7.9	6.3	85	54.8	9.9	0.02	0.22	0.06	5.4	*	<0.01	73.3
12/17/12	9.6	6.1	89	56.3	11.3	<0.02	0.20	0.07	5.7	40	0.05	81.3
Minimum	4.7	4.9	74	47.4	6.7	<0.02	0.09	0.02	2.9	<20	<0.01	60.0
Median	6.5	6.3	87	55.8	17.9	0.05	0.19	0.05	5.6	60.0	0.05	74.2
Maximum	11.9	6.5	95	60.7	24.7	0.08	0.26	0.08	12.0	160.0	0.32	93.8

This monthly sampling site on Tributary to Falling Creek was established in January of 2012. Tributary to Falling Creek is a perennial tributary in the James River watershed located in the Piedmont and Alluvium region of Chesterfield County. The stream's substrate consists primarily of sand, gravel and cobble with silt/clay observed. Flow was observed during most of the year with water consistently present, but flow was immeasurable during October and November. The water appeared stained during all but two site visits. The stream appears moderately eroded along this segment. The riparian area consists of trees and shrubs with herbaceous growth noted during the warmer months. Considering the site's location in an older residential neighborhood, and when compared to other creeks in similar locations such as Timsbury Creek WQ-78, the riparian area appears relatively undisturbed. Many different instream biotas were observed at this location including: algae, periphyton, submergent plants, *Corbicula*, fish, water striders and bacterial sheens.

Samples were obtained from the left bank at a median depth of 0.22 meters. The annual median index score (74.2%) indicated moderate chemical water quality. All annual medians of the chemical parameters were within acceptable ranges. The dissolved oxygen concentration did not violate state water quality standards during the year. However, pH (annual median: 6.3 units) violated the state water quality standard once in July. The annual mean turbidity was 5.6 NTUs. The annual ammonia nitrogen concentration was 0.05 mg/L as N. The nitrate+nitrite annual median was 0.19 mg/L as N. The annual phosphate phosphorus median concentration was elevated with 0.05 mg/L as P. The median *E. coli* concentration was 60 CFUs/100mL. The annual median fluoride value was below the reporting limit 0.15 mg/L. The potassium annual median was 3.1 mg/L. Both the fluoride and potassium annual median concentrations were consistent with expected results for groundwater.

**Site Number WQ-77**

Stream: Tributary to Proctors Creek

Site: Approximately 50 meters downhill & west of school complex on Salem Church Road, Chesterfield, Virginia

Latitude: 37.38239

Longitude: 77.48666

Watershed: James River

Stream Order: 1

Land use: Forested residential with and adjacent county school complex

Gradient: Low



## Field and Laboratory Observations:

Date	Dissolved Oxygen (mg/L)	pH (units)	Conductivity (microS/cm)	Total Dissolved Solids (mg/L)	Temperature (Degrees C)	Ammonia (mg/L as N)	Nitrate+Nitrite (mg/L as N)	Phosphate (mg/L as P)	Turbidity (NTUs)	E. Coli (CFU/100mL)	Flow m/s	Index Score %Comparison
01/24/12	11.0	6.0	58	37.0	9.6	0.02	0.26	<0.02	4.9	*	0.02	86.7
02/21/12	11.2	5.3	62	40.0	4.0	<0.02	0.25	<0.02	11.0	200	0.14	68.8
03/19/12	10.4	6.6	65	41.4	16.3	<0.02	0.22	0.03	6.3	*	0.06	73.3
04/17/12	6.3	6.0	64	41.1	18.4	0.07	0.30	0.05	6.2	120	0.08	68.8
05/16/12	6.9	6.1	57	36.4	19.1	0.08	0.35	0.03	9.0	*	0.11	60.0
06/12/12	6.2	6.0	62	39.9	20.9	0.07	0.40	0.02	8.6	80	0.02	62.5
07/16/12	5.6	6.0	67	42.8	26.0	0.04	0.24	0.05	9.3	*	0.05	60.0
08/16/12	2.4	6.0	62	40.3	25.7	0.07	0.11	0.05	10.8	100	<0.01	62.5
09/17/12	5.1	5.9	51	32.4	19.1	0.05	0.09	0.04	7.1	*	<0.01	73.3
10/22/12	3.1	6.0	59	37.9	13.1	0.02	<0.02	0.09	0.8	20	<0.01	87.5
11/19/12	4.5	6.0	74	46.9	10.4	0.03	0.05	0.07	3.7	*	<0.01	93.3
12/17/12	7.6	5.8	55	35.5	11.8	<0.02	0.06	0.05	5.4	<20	0.05	81.3
Minimum	2.4	5.3	51	32.4	4.0	<0.02	<0.02	<0.02	0.8	<20	<0.01	60.0
Median	6.2	6.0	62	40.0	17.3	0.04	0.23	0.05	6.7	90	<0.01	71.0
Maximum	11.2	6.6	74	46.9	26.0	0.08	0.40	0.09	11.0	200	0.14	93.3

This monthly sampling site on Tributary to Proctors Creek was established in January of 2012. Tributary to Proctors Creek is a perennial tributary in the James River watershed located in the Deep Coastal Plain region of Chesterfield County. The creek's substrate consists of soft silt and some clay. While water was consistently present, the flow was slow with four occasions when it was not measurable. The water appeared stained during nine assessments and clear during three. Bank erosion along this languid creek was slight to none. The riparian area was forested with undergrowth shrubs and some herbaceous cover. The riparian cover along this creek supplied abundant allochthonous input to the creek throughout the year. Periphyton was observed throughout the year. Additional biotas observed included algae, emergent plants, water striders and frogs.

Samples were obtained from the right bank at a median depth of 0.13 meters. The annual median index score (71.0%) indicated moderate chemical water quality. All annual medians of the chemical parameters were within acceptable ranges. However, both dissolved oxygen and pH violated state water quality standards on multiple observations. Dissolved oxygen (annual median 6.2 mg/L) violated the state standard twice and pH (annual median 6.0 units) on three occasions. The annual median turbidity was 6.7 NTUs, supporting the observation of a slightly stained appearance to the water. The nitrogen nutrient concentrations at this site were slightly elevated. The median ammonia nitrogen concentration was 0.04 mg/L as N. The nitrate+nitrogen annual median was 0.23mg/L as N. The phosphate phosphorus annual median was elevated with 0.05 mg/L as P. The annual median *E. coli* concentration was 90 CFUs/100mL. The median fluoride concentration was below the reporting limit 0.15 mg/L indicating levels similar to expected groundwater levels. The potassium annual median (3.0 mg/L) was also similar to expected groundwater levels.



**Site Number WQ-78**

Stream: Timsbury Creek

Site: Approximately 15 meters  
downstream of Cedar Cliff Drive road  
crossing, Chester, Virginia

Latitude: 37.32422

Longitude: 77.44601

Watershed: Appomattox River

Stream Order: 3

Land use: Residential with adjacent  
neighborhood park

Gradient: Low



## Field and Laboratory Observations:

Date	Dissolved Oxygen (mg/L)	pH (units)	Conductivity (microS/cm)	Total Dissolved Solids (mg/L)	Temperature (Degrees C)	Ammonia (mg/L as N)	Nitrate+Nitrite (mg/L as N)	Phosphate (mg/L as P)	Turbidity (NTUs)	E. Coli (CFU/100mL)	Flow m/s	Index Score %Comparison
01/24/12	10.4	6.0	65	41.3	9.4	0.03	0.21	<0.02	7.0	*	0.28	86.7
02/21/12	11.5	5.7	77	49.5	4.0	<0.02	0.22	<0.02	9.1	20	0.30	68.8
03/19/12	8.2	6.1	77	49.1	17.9	0.07	0.17	0.02	10.2	*	0.28	66.7
04/17/12	6.0	5.9	68	43.6	20.0	0.13	0.19	0.02	12.8	20	0.22	56.3
05/16/12	6.7	6.0	64	41.1	20.4	0.14	0.20	0.03	11.4	*	0.29	66.7
06/12/12	6.6	6.0	80	51.4	22.2	0.17	0.29	<0.02	9.6	20	0.19	62.5
07/16/12	6.2	6.0	79	50.6	26.1	0.06	0.27	0.03	10.6	*	0.30	60.0
08/16/12	6.3	6.1	92	58.7	25.0	0.07	0.24	0.02	8.5	40	0.10	62.5
09/17/12	7.5	6.1	85	54.7	19.5	0.07	0.39	0.03	8.2	*	0.14	60.0
10/22/12	7.8	5.9	62	40.0	13.8	0.04	0.20	0.03	10.2	40	0.21	68.8
11/19/12	7.8	6.0	84	53.6	10.9	0.05	0.26	0.03	7.0	*	0.18	66.7
12/17/12	8.2	5.9	74	47.1	10.9	0.07	0.13	0.02	8.9	<20	0.37	62.5
Minimum	6.0	5.7	62	40.0	4.0	<0.02	0.13	<0.02	7.0	<20	0.10	56.3
Median	7.7	6.0	77	49.3	18.7	0.07	0.22	0.02	9.4	20	0.25	64.6
Maximum	11.5	6.1	92	58.7	26.1	0.17	0.39	0.03	12.8	40	0.37	86.7

This monthly sampling site on Timsbury Creek was established in January of 2012. Timsbury Creek is a perennial tributary to the Appomattox River located in the Deep Coastal Plain region of Chesterfield County. The stream's substrate is comprised of sand and gravel with intermixed cobble along the top of the reach. Flow at this site was the swiftest among the sites and was observed throughout the year. The water appeared stained during ten site visits. The banks were slight to moderately eroded. The creek is bordered by a neighborhood park along the left bank and houses along the right. The width of the natural riparian area along both sides of the creek is approximately 10 meters. The natural riparian area is comprised of trees, grass and some shrub growth. Periphyton was the most often observed biota; algae, frogs, damselflies, submergent and emergent plants were also observed.

Samples were obtained from the right bank at a median depth of 0.16 meters. The annual median index score (64.6%) indicated low chemical water quality. The low chemical water quality score can be attributed to elevated nitrogen nutrient concentrations, elevated turbidity and individual violations of the state pH water quality standard. All annual medians of the chemical parameters were within acceptable ranges. On four observations, pH (annual median 6.0 units) violated the state standards. There were no violations of the state dissolved oxygen standard. The annual median turbidity (9.4 NTUs) was the highest seen among the sites. The highest annual median ammonia nitrogen concentration (0.07 mg/L as N) among sites was also observed. The annual median nitrate+nitrite concentration was 0.22 mg/L as N. The phosphate phosphorus annual median concentration was one of the three lowest concentrations seen among the sites at 0.02 mg/L as P. The *E. coli* median concentration was 20 CFUs/100mL and was among the two lowest median *E. coli* concentrations. The annual median fluoride value was below the reporting limit 0.15 mg/L. The potassium annual median was 3.0 mg/L. Both the fluoride and potassium annual median concentrations were consistent with expected results for groundwater.

**Site Number WQ-79**

Stream: Tributary to Timsbury Creek

Site: Approximately 10 meters  
downstream of Harrowgate Road crossing,  
South Chesterfield, Virginia

Latitude: 37.29478

Longitude: 77.42186

Watershed: Appomattox River

Stream Order: 2

Land use: Forested residential

Gradient: Low

*View is downstream*

Field and Laboratory Observations:

Date	Dissolved Oxygen (mg/L)	pH (units)	Conductivity (microS/cm)	Total Dissolved Solids (mg/L)	Temperature (Degrees C)	Ammonia (mg/L as N)	Nitrate+Nitrite (mg/L as N)	Phosphate (mg/L as P)	Turbidity (NTUs)	E. Coli CFU/100mL	Flow m/s	Index Score %Comparison
01/24/12	10.5	5.4	54	34.8	9.3	0.02	0.15	0.03	5.9	*	0.33	73.3
02/21/12	12.0	5.1	53	33.4	3.4	0.02	0.18	0.03	7.9	20	0.49	75.0
03/19/12	9.3	5.7	63	40.5	17.1	0.03	0.19	0.04	9.2	*	0.15	66.7
04/17/12	7.0	5.8	71	45.6	18.9	0.12	0.32	0.04	9.7	40	0.07	56.3
05/16/12	7.6	5.9	67	42.2	19.3	0.11	0.27	0.04	7.6	*	0.12	60.0
06/12/12	7.1	5.8	86	54.7	21.7	0.09	1.26	<0.02	7.3	180	0.01	62.5
07/16/12	7.7	6.2	86	55.0	27.3	0.04	0.99	0.07	12.4	*	0.50	53.3
08/16/12	6.2	6.0	96	61.3	25.1	<0.02	1.00	0.03	8.1	140	<0.01	62.5
09/17/12	6.5	5.8	89	56.3	19.5	0.02	1.44	0.04	4.6	*	0.03	66.7
10/22/12	7.4	5.8	73	47.1	14.0	<0.02	0.29	0.07	5.4	80	0.11	68.8
11/19/12	8.0	5.6	67	42.7	10.4	0.02	0.19	0.05	4.6	*	0.26	80.0
12/17/12	9.0	5.5	67	42.7	10.7	<0.02	0.11	0.06	6.6	<20	0.13	75.0
Minimum	6.2	5.1	53	33.4	3.4	<0.02	0.11	<0.02	4.6	<20	<0.01	53.3
Median	7.6	5.8	69	44.2	18.0	0.02	0.28	0.04	7.5	60.0	0.12	66.7
Maximum	12.0	6.2	96	61.3	27.3	0.12	1.44	0.07	12.4	180.0	0.50	80.0

This monthly sampling site on Tributary to Timsbury Creek was established in January of 2012. Tributary to Timsbury Creek is a perennial tributary in the Appomattox River watershed located in the Deep Coastal Plain region of Chesterfield County. Just upstream of the sampling location, a roadside tributary merges with the main branch of this Timsbury Creek tributary. The stream's substrate consists of sand, gravel and cobble. The stream exhibited strong flows most of the year with only one immeasurable observation. The water appeared stained during ten of the twelve site visits. The stream banks were well vegetated and only slightly eroded. The riparian area consisted of trees and shrubs with some herbaceous/grass growth noted during the summer months. Periphyton was consistently observed in all but one month. Also seen were algae, iron bacteria and water striders.

Samples were obtained from the right bank at a median depth of 0.15 meters. The annual median index score (66.7%) indicated low chemical water quality. The low chemical water quality score can be attributed to elevated nitrate+nitrite nutrient concentrations and violations of the state pH water quality standard. All annual medians of the chemical parameters were within acceptable ranges except pH. The annual median pH (5.8 units) violated state water quality standards. On ten occasions the pH at this location was below the state pH water quality standard. The annual median dissolved oxygen concentration was 7.5 mg/L and there were no violations of the state water quality standard throughout the year. The annual median ammonia nitrogen concentration was 0.02 mg/L as N. The highest annual median nitrate+nitrite concentration (0.28 mg/L as N) among sites was observed at this site. The phosphate phosphorus annual median concentration was 0.04 mg/L as P. The *E. coli* annual median concentration was 60 CFUs/100mL. The annual median fluoride value was below the reporting limit 0.15 mg/L. The potassium annual median was 2.9 mg/L. Both the fluoride and potassium annual median concentrations were consistent with expected results for groundwater.

## Discussion

A review of the annual median chemical water quality index values revealed that eight of the streams monitored in 2012 were characterized as having moderate or high water quality (Table 2). Low water quality was observed at the remaining two monitoring stations (Table 2).

*Table 2. Annual chemical water quality categorical observations for 10 streams of Chesterfield County, 2012*

<u>Site Number</u>	<u>Stream</u>	<u>Annual Median Score (%)</u>	<u>Category</u>
70	Powhite Creek	75.0	Moderate Quality
71	Winterpock Creek	87.5	High Quality
72	Tributary to Swift Creek	80.0	Moderate Quality
73	Little Tomahawk Creek	87.5	High Quality
74	Tributary to Falling Creek	74.2	Moderate Quality
75	Powhite Creek	81.3	Moderate Quality
76	Tributary to Falling Creek	74.2	Moderate Quality
77	Tributary to Proctor's Creek	71.0	Moderate Quality
78	Timsbury Creek	64.6	Low Quality
79	Tributary to Timsbury Creek	66.7	Low Quality

High chemical water quality was observed at two sites during 2012 (Table 2). Distinguishing characteristics of these streams' chemistries included repeated combinations of low nutrient concentrations of nitrogen and phosphorus with excellent water clarity as indicated by low turbidity. At these sites, annual median concentrations of ammonia nitrogen were both below the detection limit 0.02 mg/L. The range of nitrate+nitrite annual median concentrations amongst the two high scoring creeks was relatively wide. Little Tomahawk Creek WQ-73 had an annual median nitrate+nitrite concentration of 0.13 mg/L as N while Winterpock Creek WQ-71 had the lowest annual median nitrate+nitrite concentration of 0.02 mg/L as N. The annual median phosphate phosphorus concentrations were also low with both sites having medians less than or equal to 0.03 mg/L as P. Water clarity at the two sites with high chemical water quality was excellent with the majority of turbidity readings less than 7.0 NTUs and annual medians less than 4.0 NTUs.

Low chemical water quality was observed at two stream sites during 2012, Timsbury Creek WQ-78 and Tributary to Timsbury Creek WQ-79. Generally low chemical water quality was attributed to elevated concentrations of nutrients, violations of the state's water quality pH standard and elevated turbidity. The highest annual median ammonia nitrogen concentration and turbidity and four pH standard violations were observed at Timsbury Creek WQ-78. The highest annual median nitrate+nitrogen concentration and ten pH standard violations were observed at Tributary to Timsbury Creek WQ-79. The scores at the remainder of the monitored sites were indicative of moderate water quality.



Table 3. Annual median values for water quality parameters, 2012. Values in red indicate observations that did not meet ideal benchmarks or standards.

Site	Dissolved Oxygen (mg/L)	pH (units)	Conductivity (microS/cm)	Total Dissolved Solids (mg/L)	Temperature (Degrees C)	Ammonia (mg/L as N)	Nitrate+Nitrite (mg/L as N)	Phosphate (mg/L as P)	Turbidity (FTUs)	E. Coli CFU/100mL	Fluoride (mg/L)	Potassium (mg/L)	Flow m/s	Sample Depth (m)	Air Temp °C
WQ-70	7.0	6.5	116	74.4	17.95	0.06	0.12	0.06	6.0	40	<0.15	3.2	0.32	0.18	23
WQ-71	8.5	5.6	45	28.5	11.26	<0.02	0.02	0.03	3.8	20	0.32	2.3	0.08	0.07	22
WQ-72	7.4	6.4	104	66.5	13.93	0.02	0.08	0.03	8.9	40	0.22	3.2	0.07	0.07	20
WQ-73	9.1	6.2	125	80.3	16.42	<0.02	0.13	0.02	3.9	150	<0.15	2.3	0.21	0.04	21
WQ-74	7.5	6.4	133	85.2	18.51	0.03	0.15	0.02	6.5	150	0.25	3.5	0.13	0.18	21
WQ-75	8.1	6.4	116	74.2	16.15	0.03	0.19	0.04	4.1	50	0.20	2.8	0.21	0.07	22
WQ-76	6.5	6.3	87	55.8	17.86	0.05	0.19	0.05	5.6	60	<0.15	3.1	0.06	0.22	22
WQ-77	6.2	6.0	62	40.0	17.35	0.04	0.23	0.05	6.7	90	<0.15	2.7	0.06	0.13	23
WQ-78	7.7	6.0	77	49.3	18.69	0.07	0.22	0.02	9.4	20	<0.15	3.0	0.25	0.16	23
WQ-79	7.6	5.8	69	44.2	17.99	0.02	0.28	0.04	7.5	60	<0.15	2.9	0.13	0.15	24

In 2012, all monitored streams had annual median dissolved oxygen concentrations that met the state water quality standard of greater than or equal to 4.0 mg/L (Table 3). Three of the sites (Winterpock Creek WQ-71, Tributary to Swift Creek WQ-72 and Tributary to Proctors Creek WQ-77) had a total of seven occurrences when dissolved oxygen concentrations failed to meet the state water quality standard. Each of the seven standard violation occurred when flow was immeasurable in the creeks. This is not an uncommon observation in when flow is low. The water in the creeks would not have been able to properly aerate as a result of normal flow. The remaining sites had no violations of the state dissolved oxygen standard.

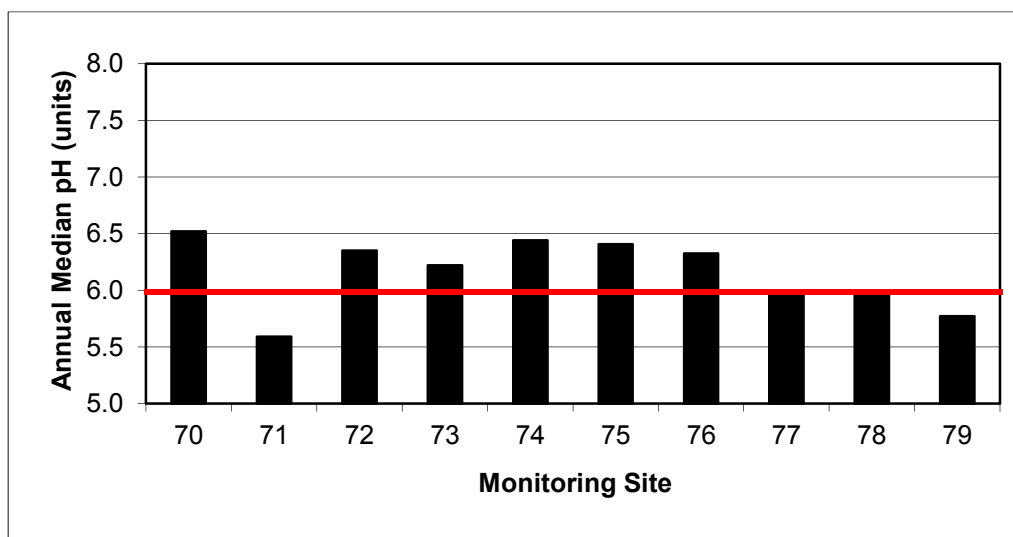


Figure 2. Annual median pH observations among 10 sites within Chesterfield County, 2012. The red bar represents Virginia Department of Environmental Quality's minimum value water quality standard (6.0 units).

In 2012, eight of the ten streams had annual median pH values that were at or above the minimum state water quality standard of 6.0 units (Figure 1). Of the eight sites with median values above 6.0 units, five sites experienced one or more instances of pH dropping below the

state water quality minimum during the year. Tributary to Timsbury Creek WQ-79 had the most observations of low pH with ten of the twelve measurements less than 6.0 units. The cause for these observations is currently unknown since the watershed is comprised of forested residential areas and forest. Depressed pH may be a natural condition of this tributary as a result of upstream wetlands driving down the pH as a result of the natural biologic activities that occur in wetlands. As mentioned in previous reports, the periodic low readings at these sites are not alarming. Low pH is typical of many streams in Virginia due to natural acidity from the surrounding soils and organic acids synthesized and released during decomposition of leaf litter and other plant matter. No sites surpassed the state standard maximum pH limit of 9.0 units during 2012.

Annual median values for specific conductivity and total dissolved solids were within acceptable limits for 2012. Tributary to Falling Creek WQ-74 had the greatest annual median conductivity (133  $\mu\text{S}/\text{cm}$ ) and total dissolved solids (85.2 mg/L) values compared to all sites. The lowest annual median conductivity and total dissolved solids among all sites were observed at Winterpock Creek WQ-71 with 45  $\mu\text{S}/\text{cm}$  and 28.5 mg/L, respectively. Overall, conductivity and total dissolved solids measurements among all sites throughout the year were lower than observed in previous years.

At all sites, instream temperature varied normally according to season and there were no observations that violated state water quality standards. Ambient air temperature during the surveys also varied seasonally with the year's survey results ranging from 5 to 32°C.

Rainfall for 2012, as reported by the Addison-Evans Water Treatment and Laboratory Facility, was approximately 26 inches; 18 inches below normal (average rainfall = 44 inches/year) for this area. Rainfall during eleven of the twelve months was below average. This rain deficit is most likely the cause for both Winterpock Creek WQ-71 and Tributary to Swift Creek WQ-72 going dry from August to October. Additionally, it would account for the multiple observations of low flow among all the sites. The least amount of rain was recorded in November with less than 1 inch of rain reported (0.14 inches).

Flow varied throughout the year at all sites during 2012. Flows during the course of the year appeared to be depressed due to the lack of rain in the region. Only three sample sites exhibited measureable flow throughout the year: Powwhite Creek WQ-70, Powwhite Creek WQ-75 and Timsbury Creek WQ-78. The majority of the flow at these creeks was consistently above 0.10 m/s. The seven remaining streams sites, experienced at least one instance of low flow (<0.01 m/s) conditions during 2012. Winterpock Creek WQ-70 and Tributary to Swift Creek WQ-72 both went dry for the last three months of the hydrologic cycle, from August to October. In previous years, most streams evaluated have not been observed dry for so many consecutive months.

Overall fluoride concentrations measured throughout the year indicated the streams sampled were not experiencing an intrusion of potable or waste water at the time of sampling. Six of the ten monitoring sites had annual median fluoride concentrations below the reporting limit 0.15 mg/L. All other annual medians were less than or equal to 0.32 mg/L. The greatest fluoride concentration was observed at Tributary to Swift Creek WQ-72 (0.55 mg/L) in December. This

concentration was greater than expected in groundwater concentrations but approximately half the expected drinking water concentration (0.94 mg/L). All other fluoride measurements at WQ-72 were within expectations for groundwater. Therefore, potable water or sewage intrusion was not suspected at this site.

Annual median potassium levels at each stream site were below concentrations that would indicate an illicit connection or discharge into the creek at the time of sampling. The greatest potassium concentration occurred in October at Tributary to Falling Creek WQ-74 measuring 4.3 mg/L. Seven of the ten sites had annual median potassium concentrations equal to or less than 3.1 mg/L. These results indicate that the concentration of potassium in county groundwater trends with the expected result of 3.1 mg/L.

Overall, ammonia nitrogen median concentrations were at acceptable levels during 2012 with three streams' annual median values greater than 0.04 mg/L as N (Powwhite Creek WQ-70, Tributary to Falling Creek WQ-76 and Timsbury Creek WQ-78; Table 3). The greatest annual ammonia nitrogen median was noted at Timsbury Creek WQ-78 (0.07 mg/L as N) contributing to its low water quality scoring. The single greatest ammonia nitrogen level measured during 2012 (0.17 mg/L as N) were recorded in June at Tributary to Swift Creek WQ-72 and Timsbury Creek WQ-78. The lowest annual median concentrations (<0.02 mg/L as N) were recorded at the two sites noted with high chemical water quality: Winterpock Creek WQ-71 and Little Tomahawk Creek WQ-73 (Table 3).

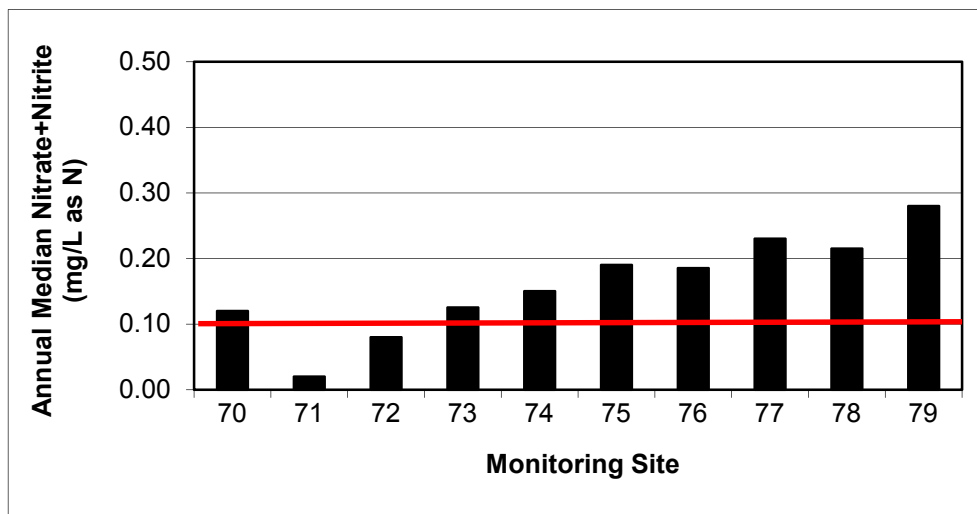


Figure 3. Annual median nitrate+nitrite nitrogen observations among 10 sites within Chesterfield County, 2012. The red bar represents the USEPA's local reference condition for Level III Ecoregion 45 streams (0.10mg/L as N).

Annual median nitrate+nitrite nitrogen concentrations were generally elevated among all sites in 2012. During the monitoring year, eight of the ten monitored sites (80%) had annual median concentrations greater than 0.10 mg/L as N (USEPA's reference condition for this ecoregion; Figure 2). Tributary to Timsbury Creek WQ-79 had the highest annual median concentration of nitrate+nitrite (0.28 mg/L as N) contributing to its low water quality scoring. In September, the greatest individual measurement of nitrate+nitrite nitrogen (1.44 mg/L as N) was also recorded at

Tributary to Timsbury Creek WQ-79. The two sites with concentrations of nitrate+nitrite nitrogen below 0.10 mg/L as N were Winterpock Creek WQ-71 and Tributary to Swift Creek WQ-72 with annual medians of 0.02 mg/L as N and 0.08 mg/L as N, respectively. Nitrate+nitrite nitrogen has continued to be the most frequently observed pollutant in Chesterfield County's monitored streams.

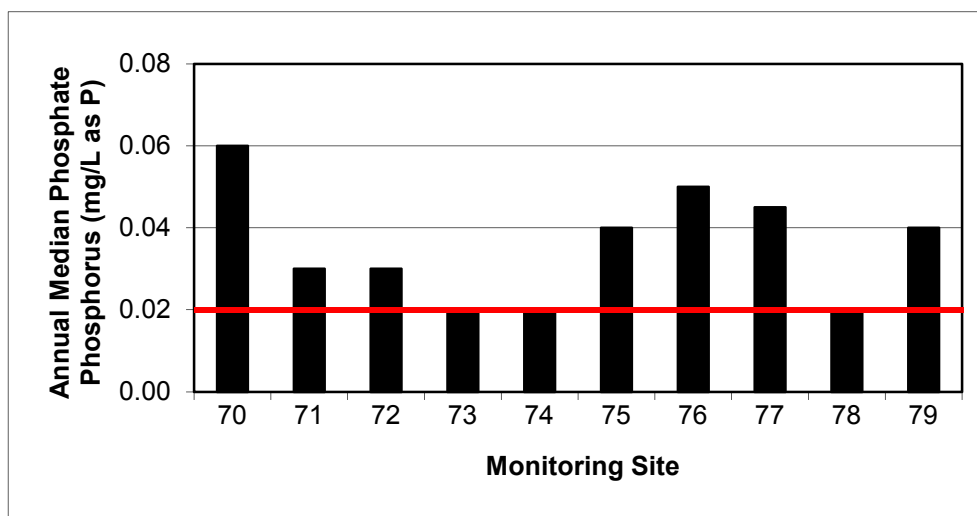


Figure 4. Annual median phosphate phosphorus observations among 10 sites within Chesterfield County, 2012. The red bar represents the Center for Watershed Protection's published ideal value for forested systems (0.02mg/L as P).

Annual median concentrations of phosphate phosphorus were elevated in each of the ten streams monitored during 2012, with all annual medians greater than or equal to 0.02 mg/L as P (Figure 3). The greatest annual median concentration (0.06 mg/L as P) was observed at Powhite Creek WQ-70. This site drains a large residential area and it is suspected that the source of the nutrient elevation is the effect of fertilizer use on lawns in the watershed. Three sites had phosphate phosphorus concentrations greater than or equal to 0.05 mg/L as P: Powhite Creek WQ-70, Tributary to Falling Creek WQ-76 and Tributary to Proctors Creek WQ-77. The greatest individual measurement of phosphate phosphorus was recorded during November at Tributary to Falling Creek WQ-74 (0.18 mg/L as P). Three streams had annual median phosphate phosphorus concentrations of 0.02mg/L as P: Little Tomahawk Creek WQ-73, Tributary to Falling Creek WQ-74 and Timsbury Creek WQ-78. Little Tomahawk had eight observations with concentrations less than or equal to 0.02 mg/L as P, contributing the findings of high chemical water quality at the site. As with nitrate+nitrite nitrogen, phosphate phosphorus remains a commonly observed pollutant throughout the county.

All annual median *E. coli* colony concentrations were below the state bacteria water quality standard of 235 CFUs/100mL. VADEQ criteria for identifying a stream as impaired for bacterial contamination is that no more than 10% of samples taken should exceed the standard of 235 CFUs/100mL. Taking into account how streams may be listed, in order for the streams monitored during the year to pass the state's examination, none of a stream's six samples tested for *E. coli* could have exceeded the state's maximum standard. Based on the state standard, three of the ten streams examined this year would have been in violation of the bacteria standard. One

of the three sites, Little Tomahawk Creek WQ-73, one of the two high water quality locations, exceeded the state standard three times during the year. These exceedences occurred during various months throughout the year (April, June and October). Further study is needed to determine if this may be a chronic condition for this site. Winterpock Creek WQ-71 and Timsbury Creek WQ-78 had the two lowest annual medians, 20 CFUs/100mL and were among the seven creeks that had no exceedences the state standard.

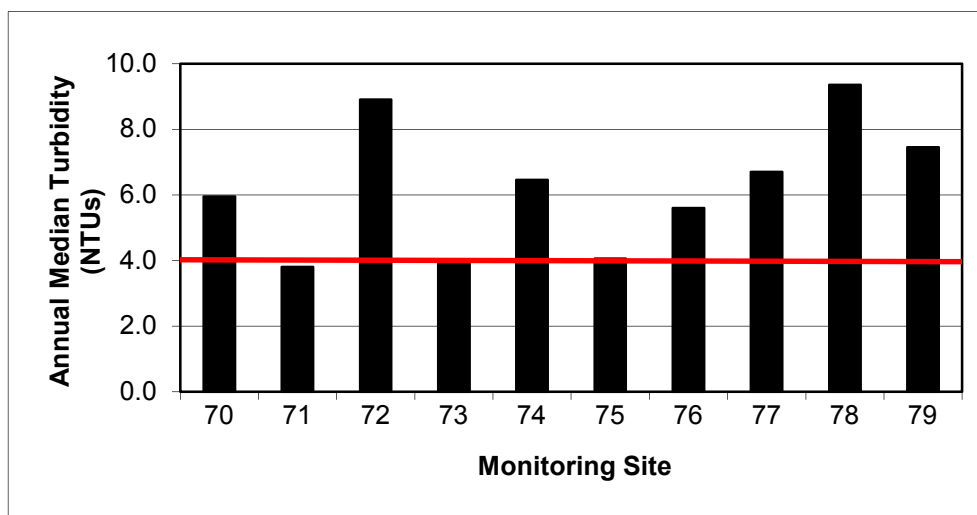


Figure 5. Annual median turbidity observations among 10 sites within Chesterfield County, 2012. The red bar represents the USEPA's local reference condition for Level III Ecoregion 45 streams (4 NTUs).

The two streams with high chemical water quality (Winterpock Creek WQ-71 and Little Tomahawk Creek WQ-73) demonstrated an annual median turbidity less than or equal to the 4.0 NTUs USEPA local reference condition. None of the streams visited this year had an annual median value that exceeded 10 NTUs (Figure 4). The greatest annual median turbidity value was observed at Timsbury Creek WQ-78 (9.4 NTUs). The lowest annual median turbidity value was observed at Winterpock Creek WQ-71 (3.8 NTUs). Overall, the turbidity measurements throughout the year indicate clear waters and suggest that the streams evaluated are not experiencing chronic elevated turbidity.

Three of the ten monitored sites are currently recorded on Virginia's impaired waters list (Table 4). Each of the three streams (Powwhite Creek WQ-70, Winterpock Creek WQ-71 and Timsbury Creek WQ-78) is impaired for not supporting aquatic life. Powwhite Creek WQ-70 is also impaired for recreational contact. The three streams each suffer from different impairment causes. Powwhite Creek WQ-70 is impaired for *E. coli* bacteria and benthic macroinvertebrates. Timsbury Creek WQ-78 is impaired for pH. Lastly, Winterpock Creek WQ-71, is listed as naturally impaired for dissolved oxygen. Of the three stream sites listed, one (Timsbury Creek WQ-78) had a quality index score that indicated low chemical water quality during 2012. The remaining streams demonstrated moderate to high chemical water quality. Strategies for bringing these streams into compliance with state standards will be developed by the Virginia Department of Environmental Quality.



Table 4. Monitoring sites assessed in 2012 that are currently listed as impaired state waters by the Virginia Department of Environmental Quality (VADEQ 2010).

Site Number	Stream	Virginia DEQ Status	Impairment On	Impairment Cause	Index Category
WQ-70	Powhite Creek	Impaired Category 5A	Recreation/ Aquatic Life	<i>E. coli</i> bacteria & Benthic Macroinvertebrate	Moderate Quality
WQ-71	Winterpock Creek	Impaired Category 4C (natural)	Aquatic Life	Dissolved Oxygen	High Quality
WQ-78	Timsbury Creek	Impaired Category 5C	Aquatic Life	pH	Low Quality

## Conclusions:

The overall chemical water quality in the monitored streams of Chesterfield County continues to be good. The majority (8) of the streams investigated during 2012 possessed moderate or high chemical water quality. Two sites, Timsbury Creek WQ-78 and Tributary to Timsbury Creek WQ-79, demonstrated low chemical water quality during 2012. The lack of quality was attributed to increased concentrations of nutrients, violations of the state's water quality pH standard and elevated turbidity. All annual medians of physical parameters were within acceptable ranges during 2012 with the exception of pH at Winterpock Creek WQ-71 and Tributary to Timsbury Creek WQ-79, where values were below the state standard. Ammonia nitrogen concentrations were at acceptable levels during 2012 with only three streams having annual median values greater than 0.04 mg/L as N. Annual median nitrate+nitrite nitrogen concentrations were generally elevated with eight of the ten monitored sites having annual median concentrations greater than 0.10 mg/L as N. Annual median concentrations of phosphate phosphorus were elevated during 2012 with each of the ten streams demonstrating some degree of phosphate phosphorus degradation. Turbidity measurements indicated clear waters throughout the county.

In 2013 the monthly monitoring program will add-back one site visited in previous years and retain nine sites evaluated in 2012. The new site will be selected from previous stream locations visited that has identified as impaired by the Watershed Assessment and Stream Protection program. Monitoring these sites throughout the year continues to provide additional information as to if these streams demonstrate impaired conditions throughout the year and/or why these sites may be impaired. The bi-monthly *E. coli* screening will continue in an effort to further establish a general baseline of expected coliform levels in county waterways throughout the year. The fluoride and potassium chemistries will still be measured on a quarterly basis for the monthly sites to continue evaluating expected groundwater quantities for both analytes.

## References

- APHA, 1995. Standard Methods for the Examination of Water and Wastewater, 19<sup>th</sup> Edition. American Public Health Association, American Waterworks Association and the Water Environment Federation. Washington D.C.
- Brown, E. & Caraco, D. 2004. Illicit Discharge Detection and Elimination: A Guidance Manual for Program Development and Technical Assessment. Center for Watershed Protection. Elliot City Maryland
- Caraco, Deb. 2001. Managing Phosphorus Inputs into Lakes III. Evaluating the Impact of Watershed Treatment. *Watershed Protection Techniques* 3(4): 791-796.
- Chesterfield County Water Quality Section, 2011. Chesterfield County Water Quality Section Field and Laboratory Instrument Standard Operating Procedures. Chesterfield County, Virginia.
- Chesterfield County Water Quality Section, 2010. *2009 Annual Summary of Water Quality Observations in Streams and Rivers of Chesterfield County*. Chesterfield County, Virginia.
- DEDNR, 1999. State of Delaware Surface Water Quality Standards, Section 11.1: General Criteria for Fresh Waters. Delaware Department of Natural Resources and Environmental Control. Delaware.
- EPA, 2000. Ambient Water Quality Criteria Recommendations: Information Supporting the Development of State and Tribal Nutrient Criteria, Rivers and Streams in Nutrient Ecoregion IX. EPA 822-B-00-019. U.S. Environmental Protection Agency Office of Water. Washington D.C.
- Kitchell, Anne. 2001. Managing Lakes for Pure Drinking Water. *Watershed Protection Techniques* 3(4): 797-812.
- KYDEP 2002. 401 KAR 5:031: Surface Water Standards. Kentucky Natural Resources and Environmental Protection Cabinet, Department for Environmental Protection, Division of Water. Kentucky.
- National Oceanic and Atmospheric Administration National Climatic Data Center Webpage [http://www.cpc.ncep.noaa.gov/products/monitoring\\_and\\_data/us.shtml](http://www.cpc.ncep.noaa.gov/products/monitoring_and_data/us.shtml)
- PADER, 2002. The Pennsylvania Code, § 93.7 Specific Water Quality Criteria. Pennsylvania Department of Environmental Resources. Pennsylvania.
- Palintest, 2003. Photometer 8000 System for Water Analysis Operation Manual. Palintest USA. Erlanger, Kentucky.
- Schueler, Thomas R. 1997a. Technical Note 92: Comparison of Forest, Urban and Agricultural Streams in North Carolina. *Watershed Protection Techniques* 2(4): 503-505.

Schueler, Thomas R. 1997b. Technical Note 94: Fish Dynamics in Urban Streams near Atlanta, Georgia. *Watershed Protection Techniques* 2(4): 511-514.

VADEQ, 2010. Virginia Department of Environmental Quality Water Quality Assessments Webpage. <http://www.deq.virginia.gov/wqa/ir2010.html>.

VADEQ, 2009. Water Quality Standards 9 VAC 25-260 et seq. State Water Control Board. Virginia Department of Environmental Quality, Richmond, Virginia.